SCADDS
USC-ISI
http://www.isi.edu/scadds

Deborah Estrin (UCLA and USC-ISI)

Ramesh Govindan (USC, USC-ISI, ICIR)

John Heidemann (USC-ISI)

Fabio Silva (USC-ISI)

Wei Ye (USC-ISI)

Chalermak Intanagonwiwat, Yan Yu, Ya Xu, Jerry Zhao

Outline

- Protocols
  - Diffusion
    - Experimental results
    - Aggregation
  - SenseIT Adaptive self-configuration support
    - S-MAC adaptive duty cycle to fit traffic
    - CEC/GAF adaptive topology
    - GEAR adaptive routing
- SenseIT support
  - Diffusion software and ns release
  - 29 Palms experimental support
- Plans for 02: Scaling in size and complexity
  - Scaling studies
    - Testbed: Measurement, Plans for expansion, External use
  - Computational model
    - complex nested queries, triggering, multiple modalities

Directed Diffusion: Background

data dissemination and coordination paradigm developed for scalable sensor networks

- **Application-specific *in-network processing* (e.g., aggregation, collaborative processing) to support long-lived, scalable, sensor networks**

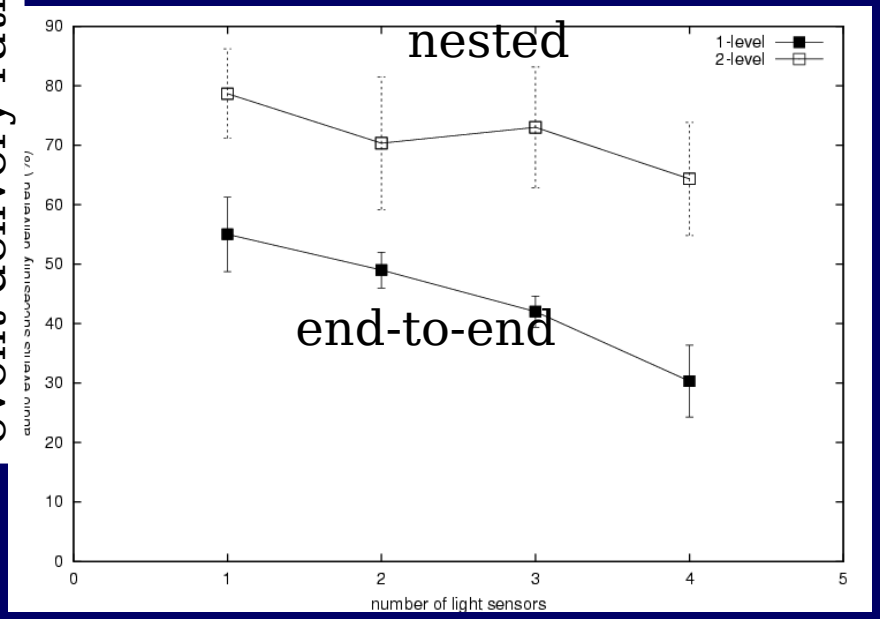
- **Data-centric communication primitives**
  - **organize system based on *named data* (not nodes)**
- **Supported with distributed algorithms using *localized interactions***
  - ***diffuse requests* and responses across network**
  - **adapt to good path with *gradient-based feedback***
  - **naturally supports *in-network aggregation* of redundant/correlated detections**

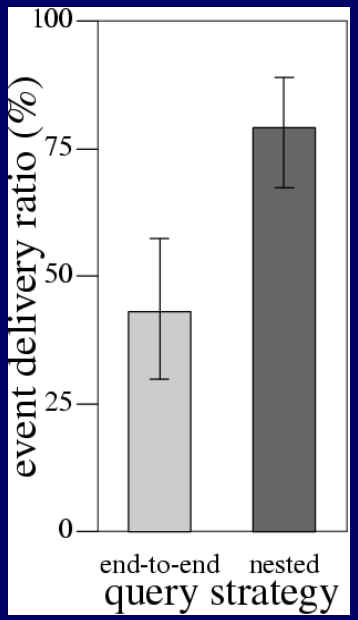
Directed Diffusion: 2001 results

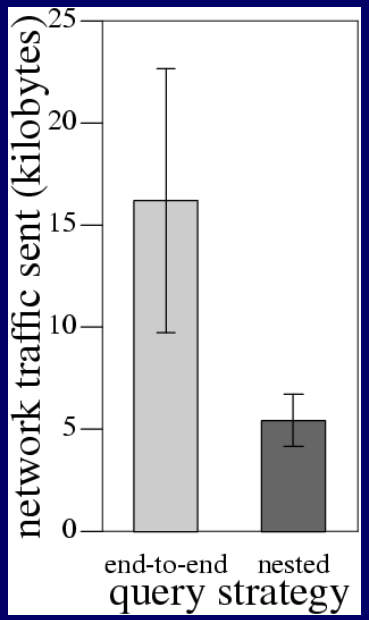
- Experimental results
- Aggregation mechanism development and evaluation
  - Intanagonwiwat, Estrin, Govindan, Heidemann (contact intanago@isi.edu)
  - Collaborated with Cornell on modeling of data-centric architectures (contact Krishnamachari, bhaskar@ee.cornell.edu)
- Future plans
- Software and simulation support
  - Silva, Haldar (contact fabio@isi.edu)

Nested Queries Experiments: ISI and 29Palms

- **SITEX'02 validates ISI-lab experiments**
  - **Used BAE-Austin's signal processing**
  - **Live, Multiple-target, real-vehicle detections**
  - **Reduces network traffic/Improves event delivery**
- **Documented APIs effectively used by many SenseIT groups**

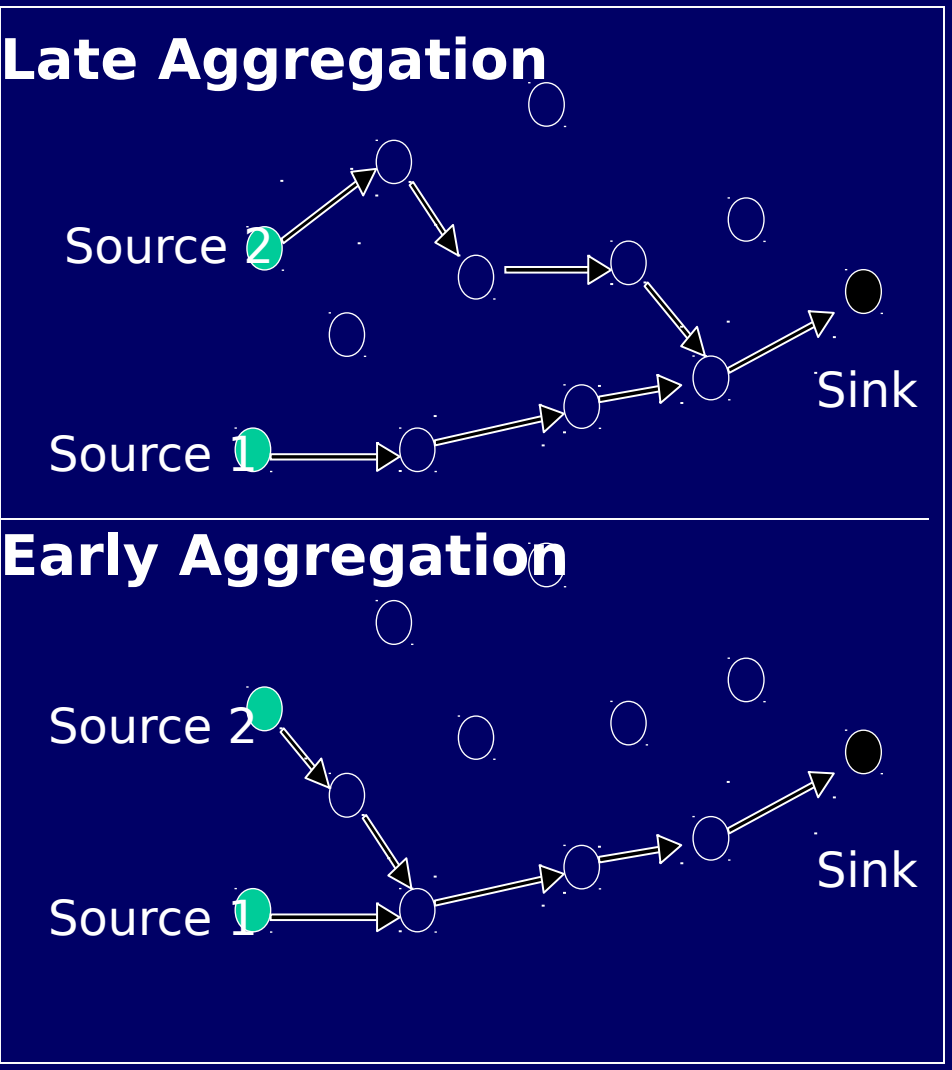






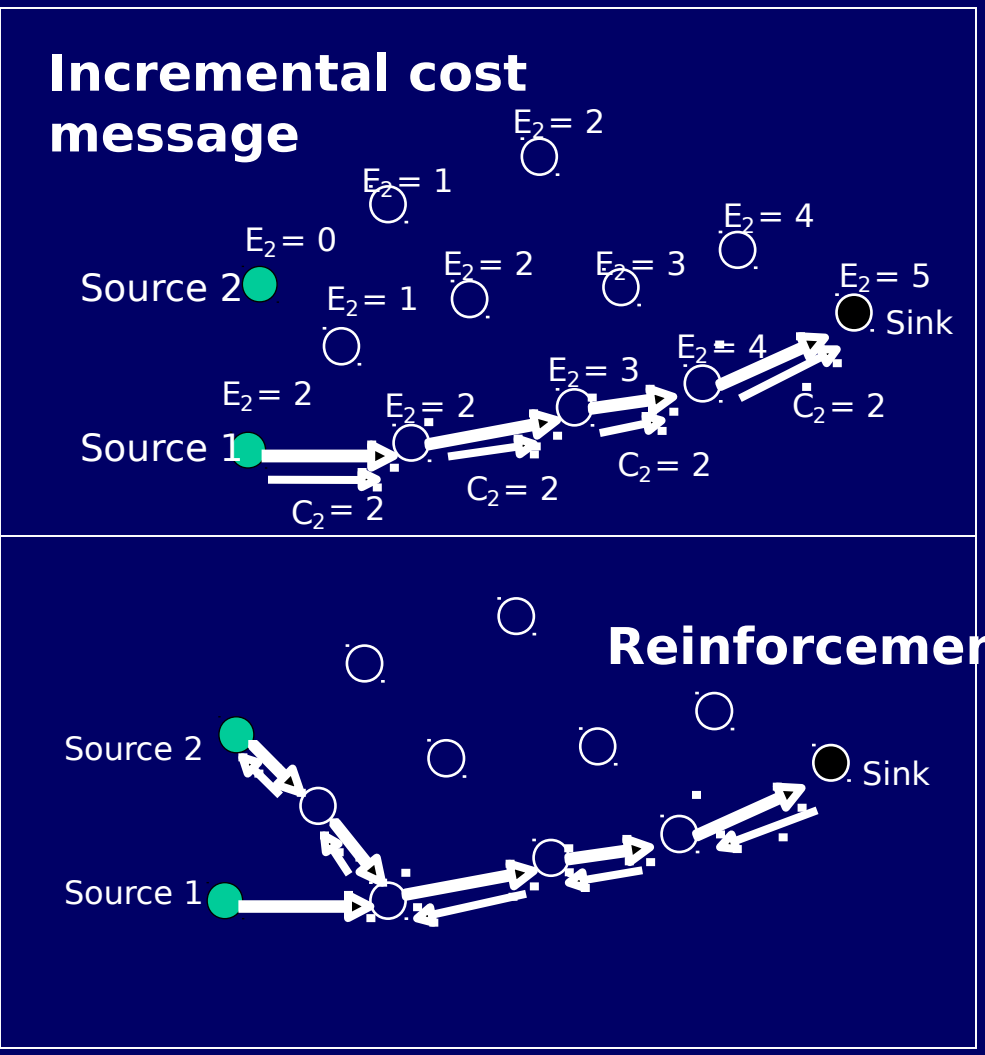
ISI Testbed Data: 2-level are nested queries 29Palms Data

Greedy Aggregation



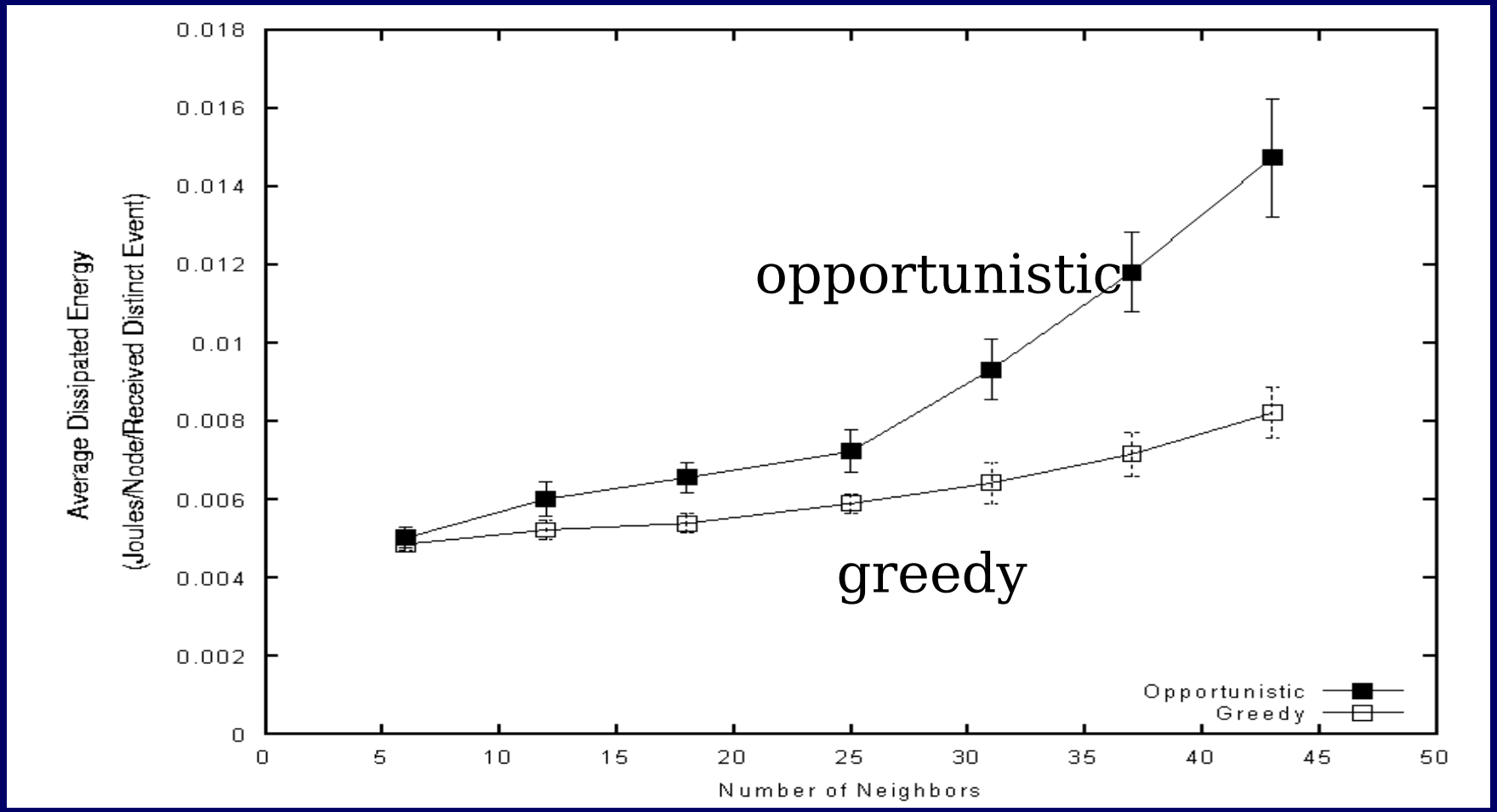
- Low-latency tree might be inefficient (late aggregation)
- Bias path selection to increase early sharing of paths (early aggregation)
- Construct greedy incremental tree (GIT)
  - establish t shortest path for first source
  - connect each other source at closest point on existing tree

Mechanisms



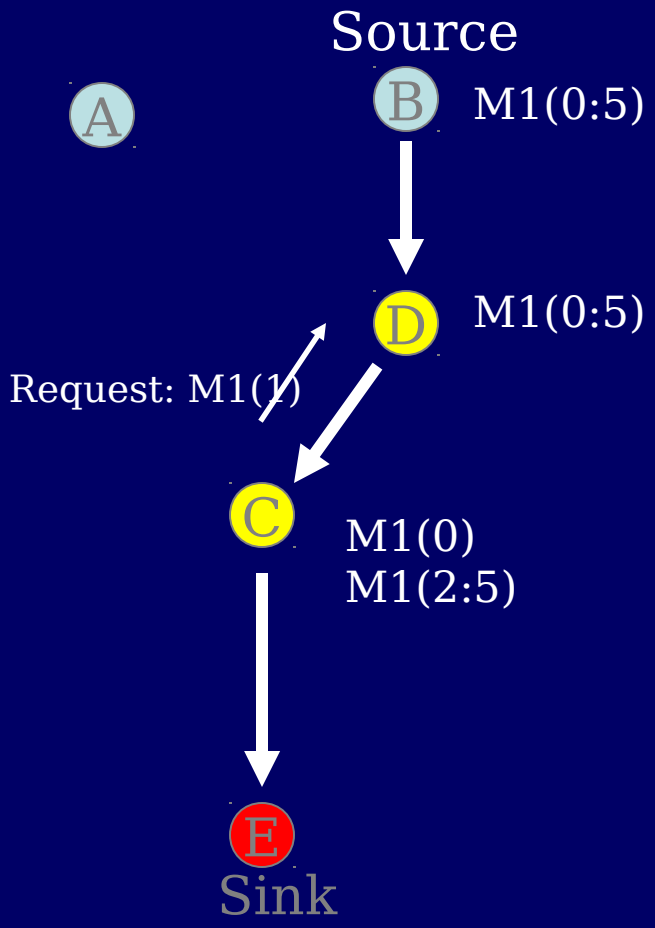
- **Path Establishment**
  - **Propagate energy cost with events**
  - **On-tree incremental cost message for finding closest point on existing tree**
  - **Path selection based on lowest energy cost (events and incremental cost messages)**
- **Path maintenance**
  - **Use greedy heuristic of weighted set-covering problem to compute ene rgy cost of an outgoing aggregate**

Simulation Results: Average Dissipated Energy



Greedy aggregation appears to outperform opportunistic aggregation only in very high-density networks

Diffusion: Future Plans



- **Big Blob**
  - **Allows transferring large objects: image, acoustic samples, etc.**
  - **Achieves reliable communication using Diffusion's in-network processing:**
    - **cache message fragments in network**
    - **request fragment retransmissions**
    - **reassemble original message**
- **Push semantics**
  - **unsolicited data push all nodes within geographic region**
  - **useful for triggering sensor wakeup during predictive tracking**
  - **easily accomplished within diffusion framework**
- **Integrated and scaled studies of Diffusion (including interaction with GEAR, S-MAC)**

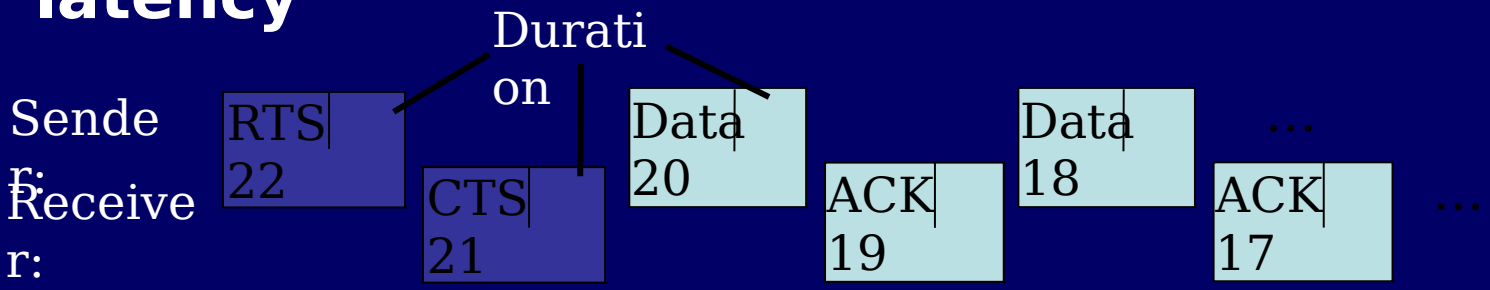
Adaptive Self Configuration Mechanisms

- S-MAC
  - Ye, Heidemann, Estrin (contact weiye@isi.edu)
- GAF/CEC adaptive topology formation
  - Xu, Heidemann, Estrin (contact yaxu@isi.edu)
- GEAR adaptive routing
  - Yu, Govindan, Estrin (contact yanyu@isi.edu)

Sensor-MAC (S-MAC) Design

- **Trade off latency and fairness for energy**
- **Major components**
  - **Periodic listen/sleep**

    - **Neighboring nodes synchronize listening for control packets**
  - **Collision avoidance similar to IEEE 802.11**
  - **Overhearing avoidance (like PAMAS)**
    - ***Duration* field informs other nodes the sleep time**
  - **Message passing: reduce control overhead & latency**

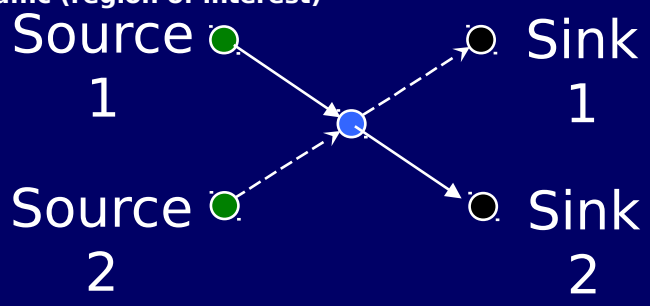


Implementation & Experiments

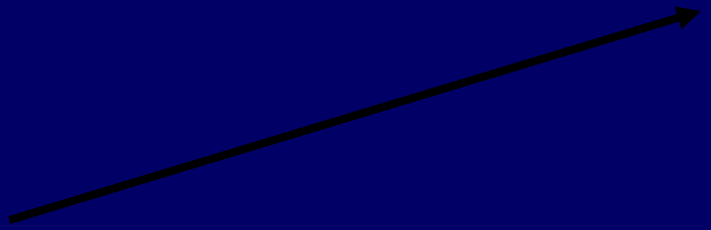
- **Modules implemented on motes & TinyOS**
  - **Simplified IEEE 802.11**
  - **Message passing with overhearing avoidance**
  - **Complete S-MAC**
- **Topology & results**

X-axis: msg inter-arrival time
msg=burst of 10 pkts
Y-axis: Energy consumed
in mJ by src nodes

- **Significant savings w/ lightly loaded, bursty traffic (region of interest)**



IEEE802.11
Overhearing avoidanc
Sensor-MAC



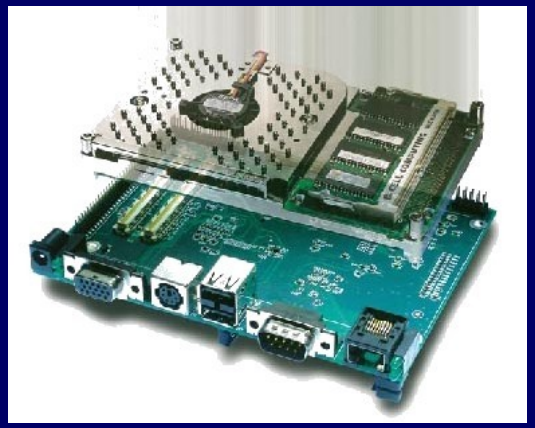
S-MAC Future Plans

- **Deploy S-MAC on large testbeds**
  - **Stand alone motes (TOS)**
  - **Mote-NICs for PC104s/Netcards/IPAQs (linux)**

S-MAC

MoteNIC

Serial cable

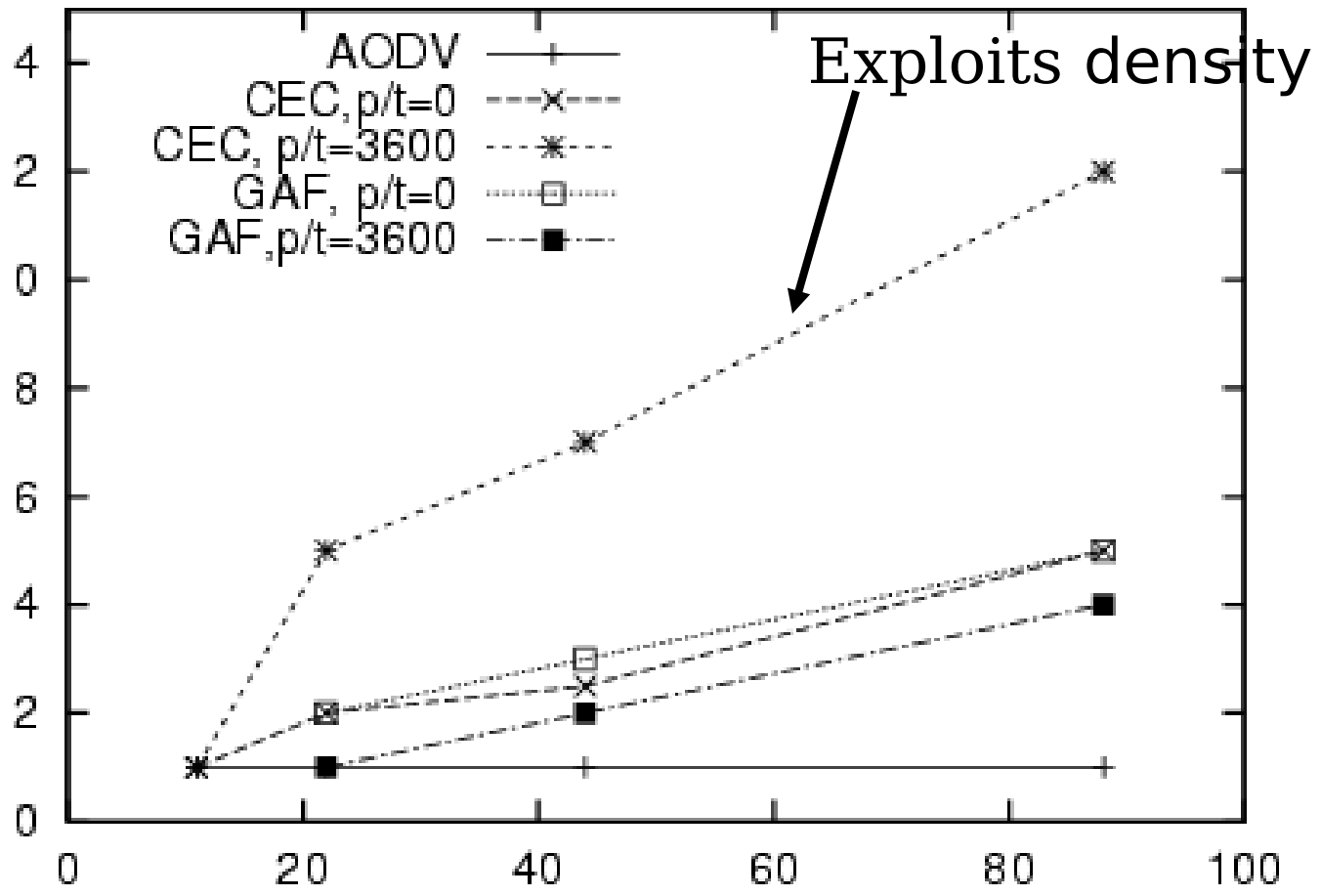


- **Large scale testing**
  - **Energy vs. Latency; parameter selection**
  - **Varying traffic models**
- **Implementation in *ns***

Cluster-based Energy Conservation (CEC)

- **Self-configuring topology/cluster formation**
  - **Exploit redundancy over time to support long lived systems**
- **Promising performance gains result from three protocol features:**
  - **Determines node-equivalence/redundancy directly-- avoids conservative decision based on indirect measure, I.e., geographic information**
  - **Lower overhead than passing around complete routing information**
  - **Improved mobility adaptation**

Network lifetime Comparison between CEC, GAF and AODV (simulation)



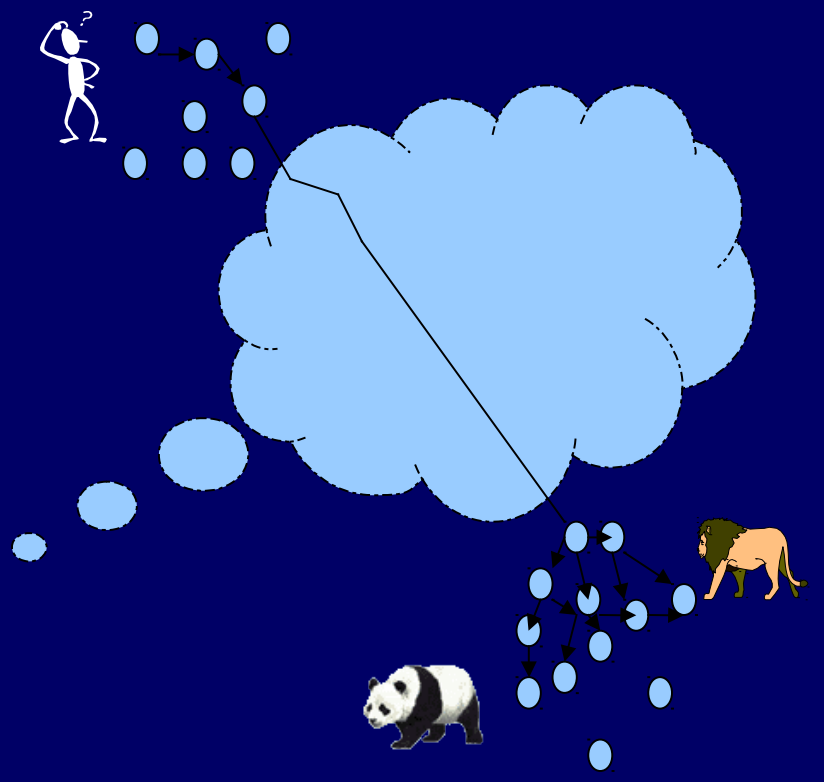
network lifetime: time when only 20% nodes remain alive

density: number of nodes in nominal radio area

Geographical and Energy Aware Routing (GEAR)

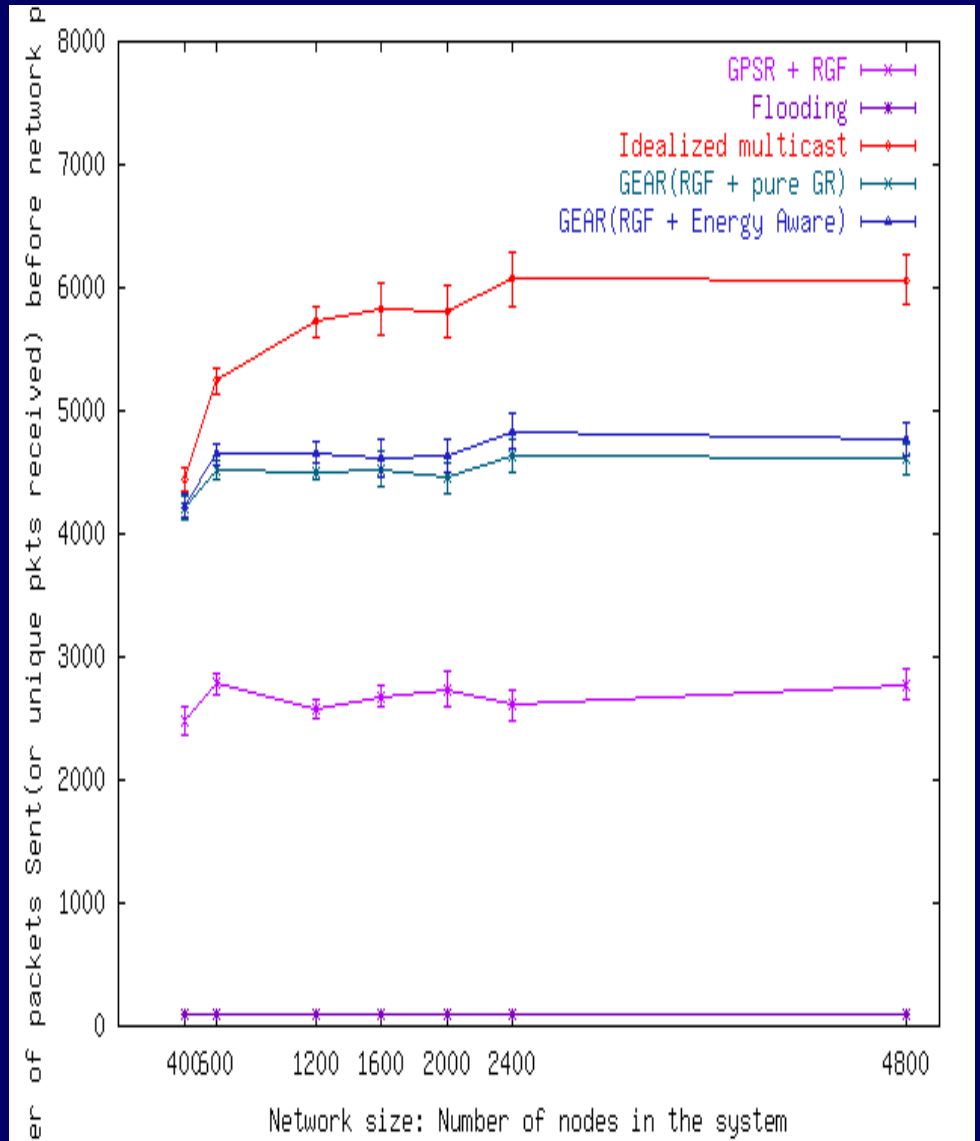
- **Forward packet (e.g., diffusion interest) to all nodes within given geographical region.**
  - **Leverage geographical information to restrict flooding, recursively disseminate data inside target region.**
  - **Extend overall network lifetime using local energy balancing techniques**
  - **Reuse routing information across multiple user queries.**

Interest 1: target1 in region R
Interest 2: target2 in region R



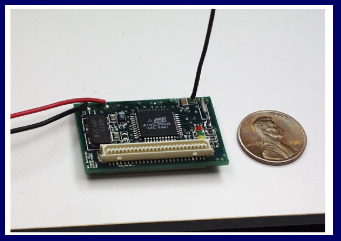
Simulation results

- **Non-uniform traffic conditions:**
  - **GEAR provides significant benefit over GPSR (~40%)**
- **Uniform traffic conditions (see paper):**
  - **GEAR provides benefit, but smaller difference from GPSR (~25%)**
- **Idealized multicast numbers overestimate benefits by excluding overhead of tree setup**
- **X-axis: network size Y-axis: number of pkts sent before partition**



GEAR Implementation and future work

- Implemented geographical subset of GEAR in diffusion distribution.
- Status: Tested it in small network.
- Plan: implement full-fledged version of GEAR, test in multi-hop network (~100 nodes, include pc104+, iPAQ, mote etc.)
  - Investigate how real-world details affect the protocol performance
  - how real world MAC affects protocol performance, and how GEAR interacts with unpredictable radio transmission, such as asymmetric, flaky links.
- Use GEAR for state distribution/collection in Quality of Task support in sensor networks.



SenseIT Program Support

- Integration, 29 Palms, support
- Available software

Support at 29 Palms

- **ISI (Fabio) Supported integration efforts at 29 Palms**
  - **BAE, BBN, Cornell, Penn State, UCLA**
  - **ISI-W's Directed Diffusion used to move:**
    - **CPA events (local collaboration, visualization)**
    - **Tracks (inter clump, GUI)**

Software Development, Distribution

- **Diffusion 3.0.7 Update**
  - **Linux i386/SH-4**
  - **WINSNG 2.0 Radios / Wired Ethernet / MoteNic**
  - **Efficiency enhancement: GEAR uses geographic information to direct interest propagation**
- **Diffusion fully integrated into *ns-2***
  - **Single diffusion code-base for concurrent development, updates to both sim and testbed**
  - **Entire Publish/Subscribe API, Filter API available in *ns-2***
  - **Jointly work by CONSER project at ISI (NSF funded)**

Future SCADDS project emphasis: Scaling in size and complexity

- **SenseSoft Track**
  Experimentation, Testbed scaling:
  - Number of nodes
    - move from 30 to 60 nodes with 100 motes
  - System complexity: increasing richness at all levels of stack
    - S-MAC, self-configuring topology, elaborate scenarios,
  - Complement with simulation
- **Research Track**
  Complex computational model for autonomous operation
  - Autonomous, nested queries
  - Quality of Task mechanisms to support autonomous tradeoffs, and adaptation to, varying resource and load levels
- **Hopefully this is not the “end”…but only the end of the beginning…**

Other related projects at UCLA and USC-ISI

- **Diffusion**
  - **Tiny-diffusion on motes under TinyOS**
  - **Sensor-coordinated actuation using diffusion for control (data-navigation for autonomous mobile, actuation)**
  - **Robomote**
- **Distributed primitives for complex autonomous operation (NSF)**
  - **Detecting/monitoring multi-mode contours, regions, data-gradients, etc.**
  - **Quality of task: dynamic, autonomous tradeoffs**
  - **Tiered architecture: collaboration among in-situ nodes in field and higher end computational and sensor assets**
- **Localization and time synchronization (NEST)**
  - **Post facto, data-centric synchronization**
  - **Self-configuring coordinate systems with acoustic ranging**